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Volume 2014
Issue 2 Spring 2014

Article 1

Spring 2014

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GianCarlo Moschini

Iowa State University, moschini@iastate.edu

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Recommended Citation

Moschini, GianCarlo (2014) "Technology and Productivity in US Corn and Soybean," *Agricultural Policy Review*: Vol. 2014 : Iss. 2 , Article 1.

Available at: <http://lib.dr.iastate.edu/agpolicyreview/vol2014/iss2/1>

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Technology and Productivity in US Corn and Soybean

by **GianCarlo Moschini**

moschini@iastate.edu

COMPETING DEMANDS

From food, feed, energy, and environmental uses are placing stress on global land resources. To deal with these challenges, much hope rests on sustaining the trend of past productivity growth by developing and adopting new technologies. In this context, there is much to learn from the US experience of tremendous yield gains achieved thanks to improved crop varieties and management practices.

Research at CARD has reexamined the statistical evidence concerning corn and soybean yields. The data used are county-level average yields from the USDA for the period 1964–2010 for non-irrigated agriculture in all US counties with significant production of these two crops. The main objective was to isolate the specific contribution of the adoption of genetically engineered (GE) varieties from other key determinants, including germplasm improvement attributable to traditional breeding, and weather conditions. To measure weather impacts, daily temperatures from the nearest weather station were used to construct monthly growing degree days variables (useful temperatures in the range of 50–86 degrees), and also excess heat degree days variables (harmful temperatures in excess of 90 degrees). We also accounted for the impact of water stress via a monthly Palmer index (which measures soil moisture relative to normal conditions). The

model also included the changing pattern of nitrogen application over the period studied.

Our results confirm the importance of weather effects on yield, a reminder of the uncertainties and risks associated with the prospect of climate change. For both corn and soybeans, we found a positive response of yields to growing degree days and a strong negative response to excess heat. For moisture, the results show that production benefits from a dry spring and a dry harvest season, other things equal, and ample moisture in the summer months enhances yield. Increased nitrogen fertilization has also contributed significantly to yield increases, particularly for corn—the US average nitrogen application rate increased from 49 lbs/acre in 1964 to its peak of 136 lbs/acre in 1985 (it has leveled off since then).

Once weather, fertilization, and county-specific differences in soil productivity are accounted for, the remaining systematic trend in yield can be attributed to the role of improved varieties. The assumption that underlying germplasm improvement due to traditional breeding has contributed the same yield advantage both before and after the introduction of GE traits in 1996 permits us to isolate the specific yield impact of widespread GE variety adoption.

Regional differences exist, not only for yield levels but also for rate of growth. Here, we specifically discuss the results pertaining to the central Corn Belt (CCB)—Iowa, Illinois, and



Indiana. These states experienced a stronger growth for both corn and soybean yields than the rest of the country (although the pattern was similar for all US growing regions). We find that during the period 1964–2010, corn yields increased on average by 1.35 bushels per acre per year without accounting for the impact of GE trait adoption. The latter appears to have made a major contribution to corn yields: going from zero adoption to complete adoption, the model implies that GE traits contribute an additional total yield gain of 20.8 bushels/acre.

The results are similar for soybeans, as far as the underlying trend is concerned. In the CCB, the estimated growth of soybean yields was on average 0.46 bushels per acre per year over the period considered. ➡

The adoption of GE varieties does not appear to have benefited soybean yields, however. In fact, the model suggests that complete adoption of the Roundup-ready trait by itself leads to a decline of 1.1 bushels/acre.

Decoupling the impact of the underlying germplasm improvement from the GE trait contribution in this manner relies on some modeling assumptions, and slightly different results are possible by changing the structure of the model. Combining the estimated effects of traditional breeding with the additional impact of GE varieties, the model was used to estimate the total predicted growth in yields over the period 2011–2030 that should be expected for normal weather realizations. Expressed as a percentage of the realized yield in 2010, the model suggests a total growth of average yields in the CCB over this 20-year period ranging between 18.7% and 31.8% for corn, and between 16.7% and 18.2% for soybeans.

The study confirms the key role of technology in sustaining productivity improvements in agriculture. Yield gains in corn and soybeans are the result of continuous breeding efforts over a long period of time, a process accelerated by the advent of biotechnology, leading to the introduction and widespread adoption of GE traits. Improved inputs go hand-in-hand with improved management practices. We noted earlier the key role played by nitrogen fertilization in corn yields. Another key practice

Realized yields at the farm level are the result of a complex process that includes genetic improvement of plant varieties, their interaction with many environmental factors, and continually improving agricultural practices and farmers' decisions driven by market conditions.

enabled by the development of modern varieties concerns seeds density, which has been steadily increasing for corn: the average planting density in the United States went from about 26,000 kernels/acre in 1995 to about 30,000 kernels/acre in 2011. As for future impacts of technology on farm practices, much interest at present surrounds the use of “big data” in agriculture whereby modern information technology is used to combine knowledge of crop attributes with data on localized soil conditions and weather forecasts, in order to provide real-time prescriptive

management advice at planting and through the growing season.

Improvements in agricultural productivity are essential in the pursuit of global food security given the challenges of population growth, climate uncertainties, environmental stress, and land degradation, as well as the expansion of land used for non-food (energy) production. Realized yields at the farm level are the result of a complex process that includes genetic improvement of plant varieties, their interaction with many environmental factors, and continually improving agricultural practices and farmers' decisions driven by market conditions. All these elements need to be better understood if the impressive productivity successes of the past are to be repeated in the future. In particular, research and innovation is key to securing the desired yield gains, and advances in biotechnology are bound to play a critical role. Policies supportive of such research, both at public universities and in industry, are vital to enable much needed continuing productivity growth in agriculture. ■

For more information, see:

Xu, Z., D.A. Hennessy, K. Sardana, and G. Moschini. 2013. “The Realized Yield Effect of Genetically Engineered Crops: U.S. Maize and Soybean.” *Crop Science* 53: 735–745.

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